APPENDIX III:

LIQUID AND PLASTIC LIMITS

* 1. INTRODUCTION

a. The Atterberg Limits. The Atterberg limits are water contents which define the limits of various stages of consistency for fine-grained soils. The liquid limit (LL) and the plastic limit (PL) define the upper and lower limits, respectively, of the plastic range of a soil; the numerical difference between these two limits expresses the plasticity of a soil and is termed the plasticity index (PI). Detailed procedures for determining the liquid and plastic limits for use in classifying soils and developing correlations with engineering properties of soils are given below, and a simplified method for determining the liquid limit is described in Appendix IIIA, ONE-POINT LIQUID LIMIT TEST. A detailed procedure for determining the shrinkage limit is given in Appendix IIIB, SHRINKAGE LIMIT TEST.

b. Definitions.

(1) Liquid Limit. The liquid limit of a soil is the water content, expressed as a percentage of the weight of oven-dried soil at which two halves of a soil pat separated by a groove of standard dimensions will close at the bottom of the groove along a distance of 1/2 in. under the impact of 25 blows in a standard liquid limit device.

(2) Plastic Limit. The plastic limit of a soil is the water content, expressed as a percentage of the weight of oven dried soil at which the soil just begins to crumble into short pieces when rolled into a thread 1/8 in. in diameter.

2. APPARATUS

a. Liquid Limit Device. A mechanical device consisting of a brass cup suspended from a carriage designed to control its drop onto a hard rubber base. A drawing showing the essential features of the device and the critical dimensions is given in Figure 1. The design of the device may vary provided that the essential functions are preserved. The device may be operated either by a hand crank or by an electric motor.

(1) Base. The base shall be hard rubber† having a D Durometer hardness of 80 to 90, and a resilience such that an 8-mm (5/16-in.) diameter polished steel ball, when dropped from a height of 25 cm (9.84 in.) will have an average rebound of at least 80% but no more than 90%. The tests shall be conducted on the finished base with feet attached.

(2) Feet. The base shall be supported by rubber feet designed to provide isolation of the base from the work surface and having an A Durometer hardness no greater than 60 as measured on the finished feet attached to the base.

(3) Cup. The cup shall be brass and have a weight, including cup hanger, of 185 to 215 g.

(4) Cam. The cam shall raise the cup smoothly and continuously to its maximum height, over a distance of at least 180° of cam rotation. The preferred cam motion is a uniformly *

† Micarta No. 221A has been used in the past. It is satisfactory as long as it meets the resilience requirement set forth for hard rubber.

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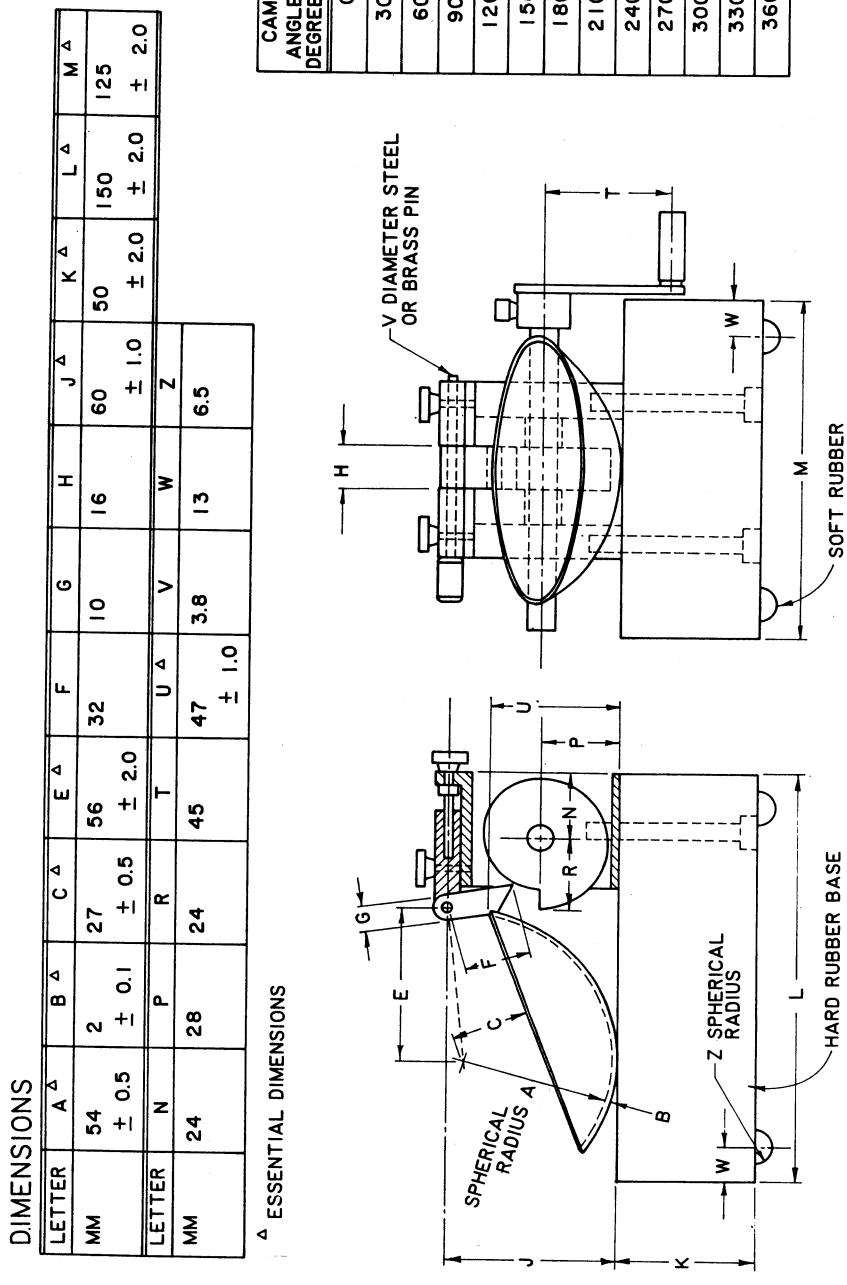

Figure 1. Hand-operated liquid limit device

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* accelerated lift curve.* The design of the cam and follower combination shall be such that there is no upward or downward velocity of the cup when the cam follower leaves the cam.

(5) Carriage. The cup carriage shall be constructed in a way that allows convenient but secure adjustment of the height of drop of the cup to 10 mm (0.394 in.). The cup hanger shall be attached to the carriage by means of a pin which allows removal of the cup and cup hanger for cleaning and inspection.

(6) Optional Motor Drive. As an alternative to the hand crank shown in Figure 1, the device may be equipped with a motor to turn the cam. Such a motor must turn the cam at 2 ± 0.1 revolutions per second, and must be isolated from the rest of the device by rubber mounts or in some other way that prevents vibration from the motor being transmitted to the rest of the apparatus. It must be equipped with an ON-OFF switch and means of conveniently positioning the cam for height of drop adjustments. The results obtained using a motor-driven device must not differ from those obtained using a manually operated device.

b. Grooving Tool. A grooving tool having dimensions as shown in Figure 2. The tool shall be made of plastic or *

* The cam and follower design in Figure1 is for uniformly accelerated (parabolic) motion. after contact and assures that the cup has no velocity at drop off. Other cam designs also provide this feature and may be used. However, if the cam-follower lift pattern is not known, zero velocity at drop off can be assured by carefully filing or machining the cam and follower so that the cup height remains constant over the last 20 to 45° of cam rotation.

DIMENSIONS

LETTER	A△	B△	C△	D△	E△	F△
MM	2 ± 0.1	11 ± 0.2	40 ± 0.5	8 ± 0.1	50 ± 0.5	2 ± 0.1
LETTER	G	H	J	K△	L△	N
MM	10 MINIMUM	13	60	10 ± 0.05	60 DEG ± 1 DEG	20

△ ESSENTIAL DIMENSIONS

'BACK AT LEAST 15 MM FROM TIP

NOTE: DIMENSION A SHOULD BE 1.9-2.0 AND DIMENSION D SHOULD BE 8.0-8.1 WHEN NEW TO ALLOW FOR ADEQUATE SERVICE LIFE

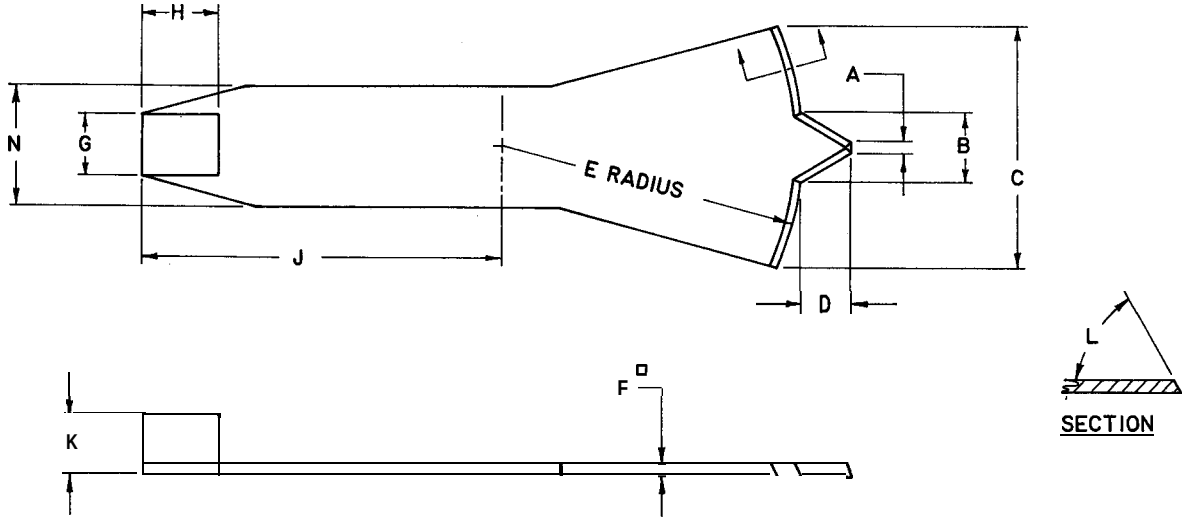
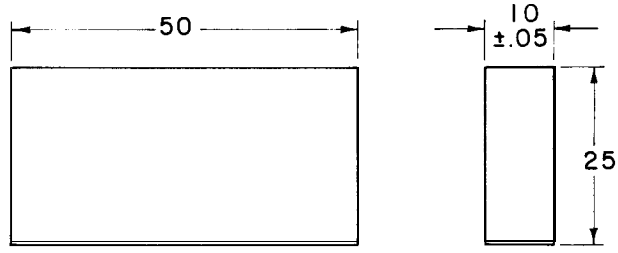


Figure 2. Grooving tool (optional height-of-drop gage attached)

noncorroding metal.* The design of the tool may vary as long as the essential dimensions are maintained. The tool may, but need not, incorporate the gage for adjusting the height of drop of the liquid limit device. *

* Polycarbonate plastic grooving tools meeting the dimensional requirements given above are available to US Government agencies through the US Army Engineer Division Laboratory, Southwestern, 4815 Cass Street, Dallas, TX 75235.

* c. Gage. A metal gage block for adjusting the height of drop of the cup, having dimensions as shown in Figure 3. The design of the tool may vary provided the gage will rest securely on the base without being susceptible to rocking, and the edge which contacts the cup during adjustment is straight, at least 10 mm (3/8 in.) wide, and without bevel or radius.



DIMENSIONS IN MILLIMETERS

Figure 3. Height of drop gage

d. Containers. Small corrosion-resistant containers with snug-fitting lids for water content specimens. Aluminum or stainless steel cans 2.5 cm (1 in.) high by 5 cm (2 in.) in diameter are appropriate.

e. Balance. A balance readable to at least 0.01 g and having an accuracy of 0.03 g within three standard deviations within the range of use. Within any 15-g range, a difference between readings shall be accurate within 0.01 g.

f. Storage Container. A container in which to store the prepared soil specimen that will not contaminate the specimen in any way, and which prevents moisture loss. A porcelain, glass, or plastic dish about 11.4 cm (4-1/2 in.) in diameter and a plastic bag large enough to enclose the dish and be folded over is adequate. *

* g. Ground Glass Plate. A ground glass plate at least 30 cm (12 in.) square by 1 cm (3/8 in.) thick for mixing soil and rolling plastic limit threads.

h. **Spatula.** A spatula or pill knife having a blade about 2 cm (3/4 in.) wide by about 10 cm (4 in.) long. In addition, a spatula having a blade about 2.5 cm (1 in.) wide and 15 cm (6 in.) long has been found useful for initial mixing of samples.

i. **Sieve.** A 20.3 cm (8 in.) diameter, 425-µm (No. 40) sieve conforming to the requirements of ASTM Specification E11 and having a rim at least 5 cm (2 in.) above the mesh. A 2-mm (No. 10) sieve meeting the same requirements may also be needed.

j. Wash Bottle. A wash bottle or similar container for adding controlled amounts of water to soil and washing fines from coarse particles.

k. Drying Oven. A thermostatically controlled oven, preferably of the forced-draft type, capable of continuously maintaining a temperature of 110 ± 5° C throughout the drying chamber. The oven shall be equipped with a thermometer of suitable range and accuracy for monitoring oven temperature.

l. Washing Pan. A round, flat-bottomed pan at least 7.6 cm (3 in.) deep, slightly larger at the bottom than a 20.3-cm (8-in.) diameter sieve.

m. Rod (Optional). A metal or plastic rod or tube 3.2 mm (1/8 in.) in diameter and about 10 cm (4 in.) long for judging the size of plastic limit threads. *

* n. Mixing Water. A supply of distilled or demineralized water.

o. Blender (Optional). A single speed blender with 1,000 ml container for preparing clay shale materials.

3. CALIBRATION OF APPARATUS

a. Inspection for Wear

(1) Liquid Limit Device. Determine that the liquid limit device is clean and in good working order. The following specific points should be checked:

(2) Wear of Base. The spot on the base where the cup makes contact should be worn no greater than 10 mm (3/8 in.) in diameter. If the wear spot is greater than this, the base can be machined to remove the wear spot provided the resurfacing does not decrease base thickness to less than that specified in 2(a) and the other dimensional relationships are maintained.

(3) Wear of Cup. The cup must be replaced when the grooving tool has work a depression in the cup 0.1 mm (0.004 in.) deep or when the edge of the cup has been reduced to half its original thickness. Verify that the cup is firmly attached to the cup hanger.

(4) Wear of Cup Hanger. Verify that the cup hanger pivot does not bind and is not worn to an extent that allows more than 3-mm (1/8 in.) side-to-side movement of the lowest point on the rim. *

* (5) Wear of Cam. The cam shall not be worn to an extent that the cup drops before the cup hanger (cam follower) loses contact with cam.

(6) Grooving Tools. Inspect grooving tools for wear on a frequent and regular basis. The rapidity of wear depends on the material from which the tool is made and the types of soils being tested. Sandy soils cause rapid wear of grooving tools; therefore, when testing these materials, tools should be inspected more frequently than for other soils. Any tool with a tip width greater than 2.1 mm must not be used. The depth of the tip of the grooving tool must be 7.9 to 8.1 mm. The width of the tip of grooving tools is conveniently checked using a pocket-sized measuring magnifier equipped with a millimeter scale. Magnifiers of this type are available for most laboratory supply companies. The depth of the tip of grooving tools can be checked using the depth measuring feature of vernier calipers.

(7) Blender Blades. Blender blades should be replaced when their overall length becomes 3 mm (1/8 in.) less than their original length.

b. Adjustment of Height of Drop. Adjust the height of drop of the cup so that the point of the cup that comes in contact with the base rises to a height of 10 ± 0.2 mm. A convenient procedure for adjusting the height of drop is as follows: place a piece of masking tape across the outside bottom of the cup parallel with the axis of the cup hanger pivot. The edge of the tape away from the cup hanger should bisect the spot on the cup that contacts the base. For new cups, placing a piece of carbon paper on the base and allowing the cup to drop several times will mark the contact spot. Attach the cup to the device and turn the crank until the cup is raised to its maximum height.*

* Slide the height gage under the cup from the front, and observe whether the gage contacts the cup or the tape (see Figure 4). If the tape and cup are both contacted, the height of drop is approximately correct. If not, adjust the cup until simultaneous contact is made. Check adjustment by turning the crank at 2 revolutions per second while holding the gage in position against the tape and cup. If a ringing or clicking sound is heard without the cup rising from the gage, the adjustment is correct. If no ringing is heard or if the cup rises from the gage1 readjust the height of drop. If the cup rocks on the gage during this checking operation, the cam follower pivot is excessively worn and the worn parts should be replaced. Always remove tape after completion of adjustment operation.

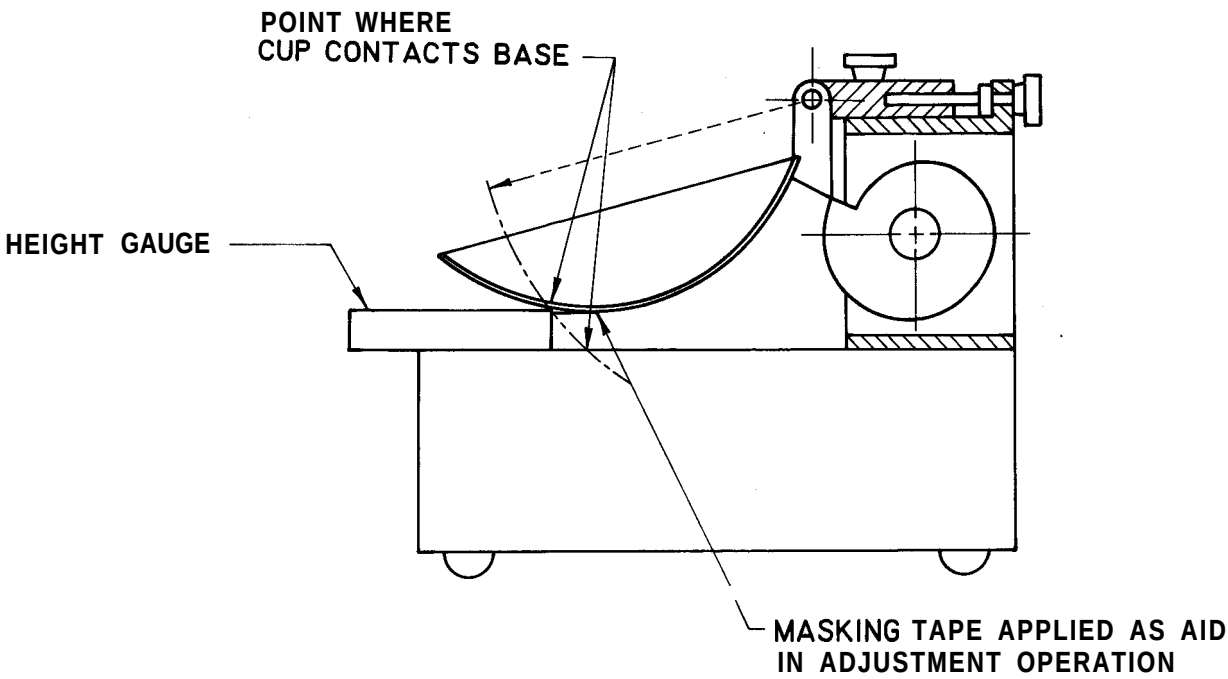


Figure 4. Calibration for height of drop *

* 4. PREPARATION OF MATERIAL

a. Selection of Material. It is essential that the same carefully prepared soil mixture be used for determining both the liquid and plastic limits. Layers of soil of different plasticity should not be mixed. Furthermore, if the natural water content is to be determined, the specimen must be taken from an identical mixture to permit valid correlations. If other test results are to be correlated with the liquid and plastic limits, the material used for the determinations must be the same as that tested. Clay shale materials require special preparation as discussed in Paragraph 9.

b. Effects of Drying. Whenever possible, soils should be at the natural water content when preparation for testing is begun. If drying has occurred before testing; the limit values may change. The plasticity of soils containing organic colloids and certain types of inorganic colloids derived from volcanic rocks is highly sensitive to drying. The effects of drying can be determined by comparing the liquid limit values of specimens in "undried," "airdried," and "ovendried" states.

c. General Preparation of Material

(1) Samples Passing the 425-µm (No. 40) Sieve. When by visual and manual procedures, it is determined that the sample has little or no material retained on the 425-µm (No. 40) sieve, prepare a specimen of 150 to 200 g by mixing thoroughly with distilled or demineralized water on the glass plate using the spatula. If desired, soak soil in a storage dish with small amount of water to soften the soil before the start of mixing. Adjust the water content of the soil to bring it to a consistency that would require 15 to 25 blows of the liquid limit device to *

* close the groove. The time taken to adequately mix a soil will vary greatly depending on the plasticity and initial water content. Initial mixing times of more than 30 min may be needed for stiff, fat clays. If, during mixing, a small percentage of material is encountered that would be retained on a 425-µm (No. 40) sieve, remove these particles by hand, if possible. If it is impractical to remove the coarser material by hand, remove small percentages (less than about 15%) of coarser material by working the specimen through a 425-µm (No. 40) sieve using a piece of rubber sheeting, a rubber stopper, or other convenient device provided the operation does not distort the sieve or degrade material that would be retained if the washing method described in the next paragraph were used. If larger percentages of coarse material are encountered during mixing, or it is considered impractical to remove the coarser material by the methods just described, wash the sample as described in the next paragraph. When the coarse particles found during mixing are concretions, shells, or other fragile particles, do not crush these particles to make them pass a 425-µm (No. 40) sieve, but remove by hand or by washing. Place the mixed soil in the storage dish, cover to prevent loss of moisture, and allow to stand for at least 16 hr (overnight). After the standing period and immediately before starting the test, thoroughly remix the soil.

(2) Samples Containing Material Retained on a 425-µm (No. 40) Sieve

(a) Select a sufficient quantity of soil at natural water content to provide 150 to 200 g of material passing the 425-µm (No. 40) sieve. Place in a pan or dish and add sufficient distilled or demineralized water to cover the soil. Allow to soak until all lumps have softened and the fines no longer adhere to the surfaces of the coarse particles. *

* (b) When the sample contains a large percentage of material retained on the 425-µm (No. 40) sieve, perform the following washing operations in increments, washing no more than 0.5 kg (1 lb) of material at one time. Place the 425-µm (No. 40) sieve in the bottom of the clean pan. Pour the soil water mixture onto the sieve. If gravel or coarse sand particles are present, rinse as many of these as possible with small quantities of water from a wash bottle and discard. Alternatively, pour the soil water mixture over a 2-mm (No. 10) sieve nested atop the 425-µm (No. 40) sieve, rinse the fine material through and remove the 2-mm (No. 10) sieve. After washing and removing as much of the coarser material as possible, add sufficient water to the pan to bring the level to about 13 mm (1/2 in.) above the surface of the 425-µm (No. 40) sieve. Agitate the slurry by stirring with the fingers while raising and lowering the sieve in the pan and swirling the suspension so that fine material is washed from the coarser particles. Disaggregate fine soil lumps that have not slaked by gently rubbing them over the sieve with the fingertips. Complète the washing operation by raising the sieve above the watersurface and rinsing the material retained with a small amount of clean water. Discard material retained on the 425-µm (No. 40) sieve.

(c) Reduce the water content of the material passing the 45-µm (No. 40) sieve until it approaches the liquid limit. Reduction of water content may be accomplished by one or a combination of the following methods: (a) exposing the air currents at ordinary room temperature, (b) exposing to warm air currents from a source such as an electric hair dryer, (c) filtering in a Buckner funnel or using filter candles, (d) decanting clear water from surface of suspension, or (e) draining in a colander or plaster of paris dish lined with high retentivity, *

* high wet-strength filter paper.* If a plaster of paris dish is used, take care that the dish never becomes sufficiently saturated that it fails to actively absorb water into its surface. Thoroughly dry dishes between uses. During evaporation and cooling, stir the sample often enough to prevent overdrying of the fringes and soil pennacles on the surface of the mixture. For soil samples containing soluble salts, use a method of water reduction such as (a) or (b) that will not eliminate the soluble salts from the test specimen.

(d) Thoroughly mix the material passing the 425-um (No. 40) sieve on the glass plate using the spatula. Adjust the water content of the mixture, if necessary, by adding small increments of distilled or demineralized water or by allowing the mixture to dry at room temperature while mixing on the glass plate. The soil should be at a water content that will result in closure of the groove in 15 to 25 blows. Return the mixed soil to the mixing dish, cover to prevent loss of moisture, and allow to stand for at least 16 hr. After the standing period, and immediately before starting the test, remix the soil thoroughly.

5. LIQUID LIMIT

a. Procedure

(1) Place a portion of the prepared soil in the cup of the liquid limit device at the point where the cup rests on the base, squeeze it down, and spread it into the cup to a depth of about 10 mm at its deepest point, tapering to form an *

* S&S 595 filter paper in 32 cm circles has been found satisfactory.

* approximately horizontal surface. Take care to eliminate air bubbles from the soil pat, but form the pat with as few strokes as possible. Heap the unused soil on the glass plate and cover with the inverted storage dish or a wet towel.

(2) Form a groove in the soil pat by drawing the tool, beveled edge, forward through the soil on a line joining the highest point to the lowest point on the rim of the cup. When cutting the groove, hold the grooving tool against the surface of the cup and draw in an arc maintaining the tool perpendicular to the surface of the cup throughout its movement (see Figure 5).

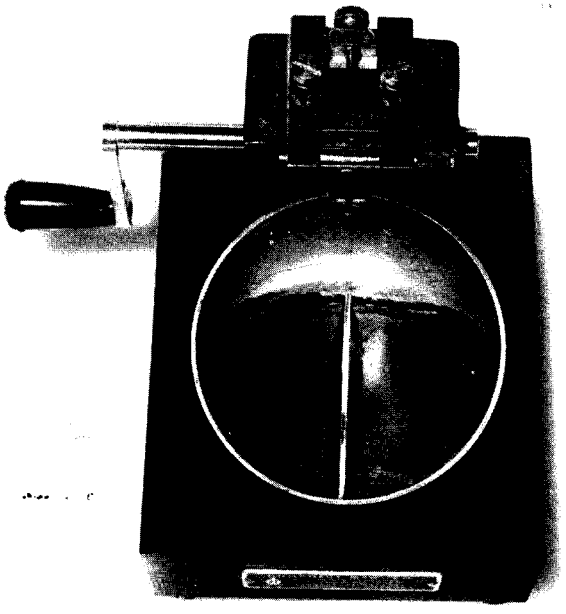


Figure 5. Grooved soil pat in liquid limit device

In soils where a groove cannot be made in one stroke without tearing the soil cut the groove with several strokes of the grooving tool. Alternately, cut the groove to slightly less than required dimensions with a spatula and use the grooving tool to bring the groove to final dimensions. Exercise extreme care to prevent sliding the soil pat relative to the surface or the cup. *

* (3) Verify that no crumbs of soil are present on the base or the underside of the cup. Lift and drop the cup by turning the crank at a rate of 1.9 to 2.1 drops per second until the two halves of the soil pat come in contact at the bottom of the groove along a distance of 13 mm (1/2 in.) (see Figure 6). Use the end of the grooving tool (Figure 2) or a scale to verify that the groove has closed 13 mm (1/2 in.).

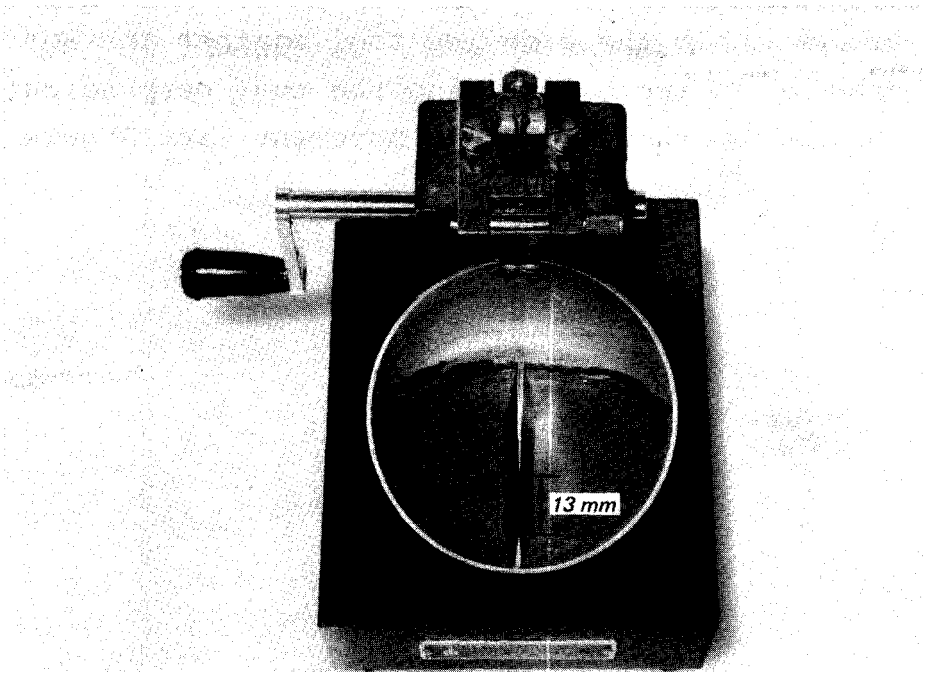


Figure 6. Soil pat after groove has closed

(4) Verify that an air bubble has not caused premature closing of the groove by observing that both sides of the groove have flowed together with approximately the same shape. If a bubble has caused premature closing of the groove, reform the soil in the cup by adding a small, amount of soil to make up for that lost in the grooving operation and repeat 5a(1) through 5a(3). If the soil slides on the surface of the cup, repeat 5a(1) through 5a(3) at a higher water content. If, after several trials at successively higher water contents, the soil pat *

* continues to slide in the cup or if the number of blows required to close the groove is always less than 25, record that the liquid limit could not be determined, and report the soil as non-plastic without performing the plastic limit test.

(5) Record the number of drops (N) required to close the groove. Remove a slice of soil approximately the width of the spatula extending from edge to edge of the soil cake at right angles to the groove and including that portion of the groove in which the soil flowed together, place in a weighed container, and cover.

(6) Return the soil remaining in the cup to the glass plate. Wash and dry the cup and grooving tool and reattach the cup to the carriage in preparation for the next trial.

(7) Remix the entire soil specimen on the glass plate to reduce the water content of the soil and increase the number of blows required to close the groove. Repeat 5a(1) through 5a(6) for at least three additional trials producing successively greater numbers of blows to close the groove. Preferably, two trials should produce closure in 25 blows or less, and two trials should produce closure in 25 blows or more.

(8) Determine the water content (WN) of the soil specimen from each trial in accordance with the procedure in Appendix I, WATER CONTENT - GENERAL. Make all weighings on the same balance. Initial weighings should be performed immediately after completion of the test. If the test is to be interrupted for more than about 15 min, the specimens already obtained should be weighed at the time of the interruption. *

b. Calculations.

(1) Plot the relationship between the water content, W_N, and the corresponding number of drops, N, of the cup on a semilogarithmic graph with the water content as ordinates on the arithmetical scale, and the number of drops as abscissas on the logarithmic scale. See Plate III-1 for an example data form. Draw the best straight line through the four or more plotted points.

(2) Take the water content corresponding to the intersection of the line with the 25-drop abscissa as the liquid limit of the soil. Computational methods may be substituted for the graphical method for fitting a straight line to the data and determining the liquid limit.

6. PLASTIC LIMIT

a. Preparation of Test Specimen. Select a 20-g portion of soil from the material prepared for the liquid limit test, either after the second mixing before the test, or from the soil remaining after completion of the test. Reduce the water content of the soil to a consistency at which it can be rolled without sticking to the hands by spreading and mixing continuously on the glass plate. The drying process may be accelerated by exposing the soil to the air current from an electric fan or by blotting with paper that does not add any fiber to the soil such as hard surface paper toweling or high wet strength filter paper.

b. Procedure

(1) From the 20-g mass, select a portion of 1.5 to 2.0 g. Form the test specimen into an ellipsoidal mass. Roll *

* this mass between the palm or fingers and the ground-glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. A normal rate of rolling for most soils should be 80 to 90 strokes per minute counting a stroke as one complete motion of the hand forward and back to the starting position. This rate of rolling may have to be decreased for very fragile soils. The thread shall be further deformed on each stroke so that its diameter is continuously reduced; and its length extended until the diameter reaches 3.2 ± 0.5 mm (0.125 ± 0.020 in.), taking no more than 2 minutes to complete the rolling operation. A 3.2-mm (1/8-in.) diameter rod or tube is useful for frequent comparison with the soil thread to ascertain when the thread has reached the proper diameter especially for inexperienced operators. The amount of hand or finger pressure required will vary greatly according to the soil. Fragile soils of low plasticity are best rolled under the outer edge of the palm or at the base of the thumb. When the diameter of the thread becomes 3.2 mm, break the thread into several pieces. Squeeze the pieces together, knead between the thumb and first finger of each hand, reform into an elliposidal mass, and reroll. Continue this alternate rolling to a thread 3.2 mm in diameter, gathering together, kneading and rerolling, until the thread crumbles under the pressure required for rolling, and the soil can no longer be rolled into a 3.2-mm diameter thread (see -Figure 7) It has no significance if the thread breaks into threads of shorter length. Roll each of these shorter threads to 3.2 mm in diameter. The only requirement for continuing the test is that they are able to be reformed into an ellipsoidal mass and rolled out again. The operator shall at no time attempt to produce failure at exactly 3.2 mm diameter by allowing the thread to reach 3.2 mm, then reducing the rate of rolling or the hand pressure, or both, while continuing the rolling without further deformation until the thread falls apart. It is permissible, *

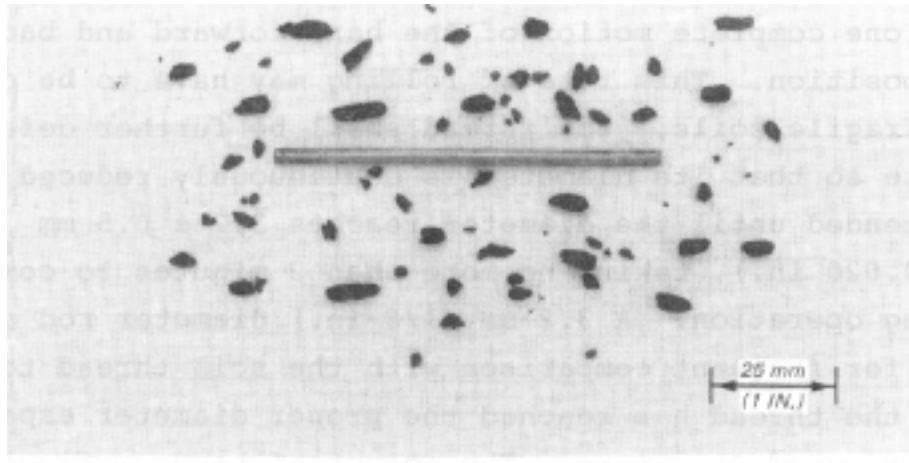


Figure 7. Lean clay soil at the plastic limit

however, to reduce the total amount of deformation for feebly plastic soils by making the initial diameter of the elliposidal mass nearer to the required 3.2 mm final diameter. If crumbling occurs when the thread has a diameter greater than 3.2 mm, this shall be considered a satisfactory end point provided the soil has been previously rolled into a thread 3.2 mm in diameter. Crumbling of the thread will manifest itself differently with the various types of soil. Some soils fall apart in numerous small aggregations of particles, others may form an outside tubular layer that starts splitting at both ends. The splitting progresses toward the middle, and finally,the thread falls apart in many small platy particles. Fat clay soils require much pressure to deform the thread, particularly as they approach the plastic

* limit. With these soils, the thread breaks into a series of barrel-shaped segments about 3.2 to 9.5 mm (1/8 to 3/8 in.) in length.†

(2) Gather the portions of the crumbled thread together and place in a weighed container. Immediately cover the container.

(3) Select another 1.5 to 2.0 g portion of soil from the original 20-g specimen and repeat the operations described in 17.1 and 17.2 until the container has at least 9 g of soil.

(4) Repeat 17.1 through 17.3 to make another container holding at least 9 g of soil. Determine the water content, in percent, of the soil contained in the containers in accordance with the procedure given in Appendix I, WATER CONTENT - GENERAL. Make all weighings on the same balance.

c. Calculations. Compute the average of the two water contents. If the difference between the two water contents is greater than two percentage points, repeat the test. The plastic limit is the average of the two water contents.

7. PLASTICITY INDEX

a. Calculations. Calculate the plasticity index as follows:

$$PI = LL - PL$$ *

† A. Casagrande, R. C. Hirschfield, and S. J. Poulos, Third Progress Report on Investigation of Stress-Deformation and Strength Characteristics of CompactedClays, Soil Mechanics Series No. 70, Harvard University (Cambridge, Mass., November 1963).

* where

LL = the liquid limit

PL = the plastic limit

Both LL and PL are whole numbers. If either the liquid limit or plastic limit could not be determined, or if the plastic limit is equal to or greater than the liquid limit, report the soil as nonplastic, NP.

b. Plasticity chart. Errors in computing the liquid or plastic limits sometimes can be detected by plotting the values of liquid limit versus plasticity index on the plasticity chart? as shown in Figure 8. The upper limit line starts from a liquid limit of 8 at a plasticity index of 0 and rises toward the right with a slope of 9 vertically on 10 horizontally; the equation of the upper limit line, therefore, is PI= 0.9 (LL - 8). A plot of liquid limit versus plasticity index for natural soils has never been known to fall above the upper limit line. Plate III-2 is a suggested form for the graphical correlation of the various Atterberg limits data within a project or testing assignment.

8. REPORT

a. Report the following information:

(1) Sample identifying information, *

† US Army Engineer Waterways Experiment Station, The Unified Soil Classification System, Technical Memorandum No. 3-357, Vol 1 (Vicksburg, Miss., March 1953, revised April 1960). An abridged version of the material in this report is presented in Military Standard MIL-STD-619A, 20 March 1962.

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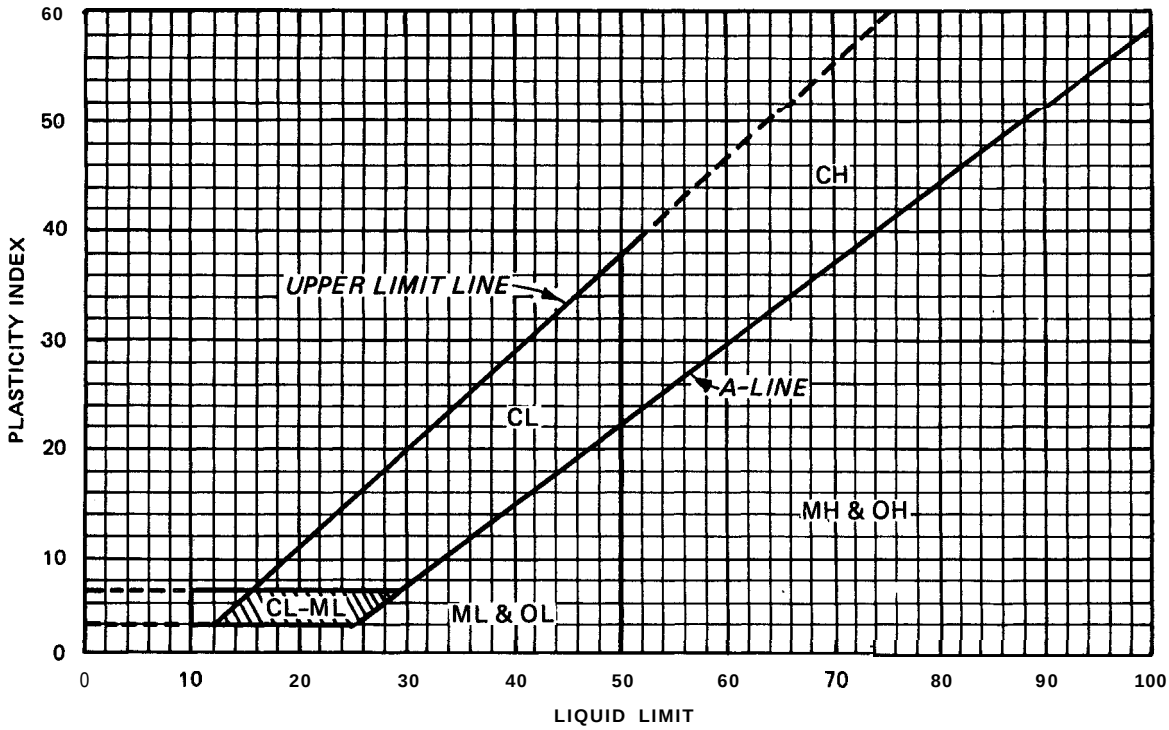


Figure 8. Plasticity chart showing classification group symbols

(2) Any special specimen selection process used such as removal of sand lenses from undisturbed sample,

(3) Liquid limit, plastic limit, and plasticity index to the nearest whole number and omitting the percent designation. If the liquid limit or plastic limit is equal to or greater than the liquid limit, report the soil as nonplastic, NP,

(4) An estimate of the percentage of sample retained on the 425-µm (No. 40) sieve, and

(5) Procedure by which liquid limit was performed, if it differs from the multipoint method. *

* 9. PREPARING CLAY SHALE MATERIAL FOR TESTING

a. General. Investigations have shown that classification indexes of clay shale materials are affected by air-drying and slaking, by oven-drying and slaking, by the type and duration of mechanical dispersing, and by other variations in procedure. While the methods for preparing clay shale material for testing should cover a sufficient range of disaggregation efforts to assess the strength of interparticle bonds, the number of variables allowed to influence the indexes must be minimized by standardized procedures to prevent the classification of each material becoming a minor research project in itself. Therefore, three standard methods of processing clay shale material will be used. These will be referred to as the blenderized, undried, and air-dried methods.

The primary method is to test material that has been essentially completely disaggregated by high-speed blenderizing; this method will provide a reference value and it should be used for all clay shale samples on which Atterberg limits are to be determined. To provide additional indexes as desired, material that has not been subjected to any drying and material that has been subjected to a single cycle of air-drying and soaking may be tested. These two methods should be used on sufficient representative samples to cover the range of samples identified by the primary method.

b. Standard Methods. When material is to be prepared by all three processing procedures, exercise care that the parent material for the batches is similar. Divide the piece of sample selected by a vertical cut into two parts with one piece about twice as large as the other. Shave the smaller piece into distilled water to produce the undried batch, and use the larger *

* piece to produce the other two batches. Figure 9 shows a flow diagram of the three preparation methods and indicates when separation of batches is required. Material may be taken from each of the three batches and used for Atterberg limits determinations without further processing. Details of each procedure are as follows.

(1) Blenderized (primary method). Shave or shred material at essentially natural water content and dry to a constant weight in an atmosphere with a temperature less than 50° C and a relative humidity less than 30 percent. After a constant weight is attained (and after a drying period of at least 48 hr), soak the material in distilled water for at least 48 hr.

(a) Place about 500 ml of the slurry in the 1,000-ml glass container (available from any laboratory supply company) of a Waring single-speed blender. Make the initial water content of the slurry above 300 percent or more than twice the estimated liquid limit (blenderized), whichever is greater. Typically, the weight of dry soil in the blender at any one time should not exceed 150 g.

(b) Blenderize the slurry without interruption for 10 min and then wash through a 425-µm (No. 40) sieve. Remove excess water using a plaster of Paris dish lined with filter paper. Work material at a water content above the liquid limit in a thin layer on a glass plate with a steel spatula until no further reduction in the size of lumps can be achieved.

(2) Undried. Shave or shred material at essentially natural water content, immediately place in distilled water, and soak for at least 48 hr. After removing excess water by *

*

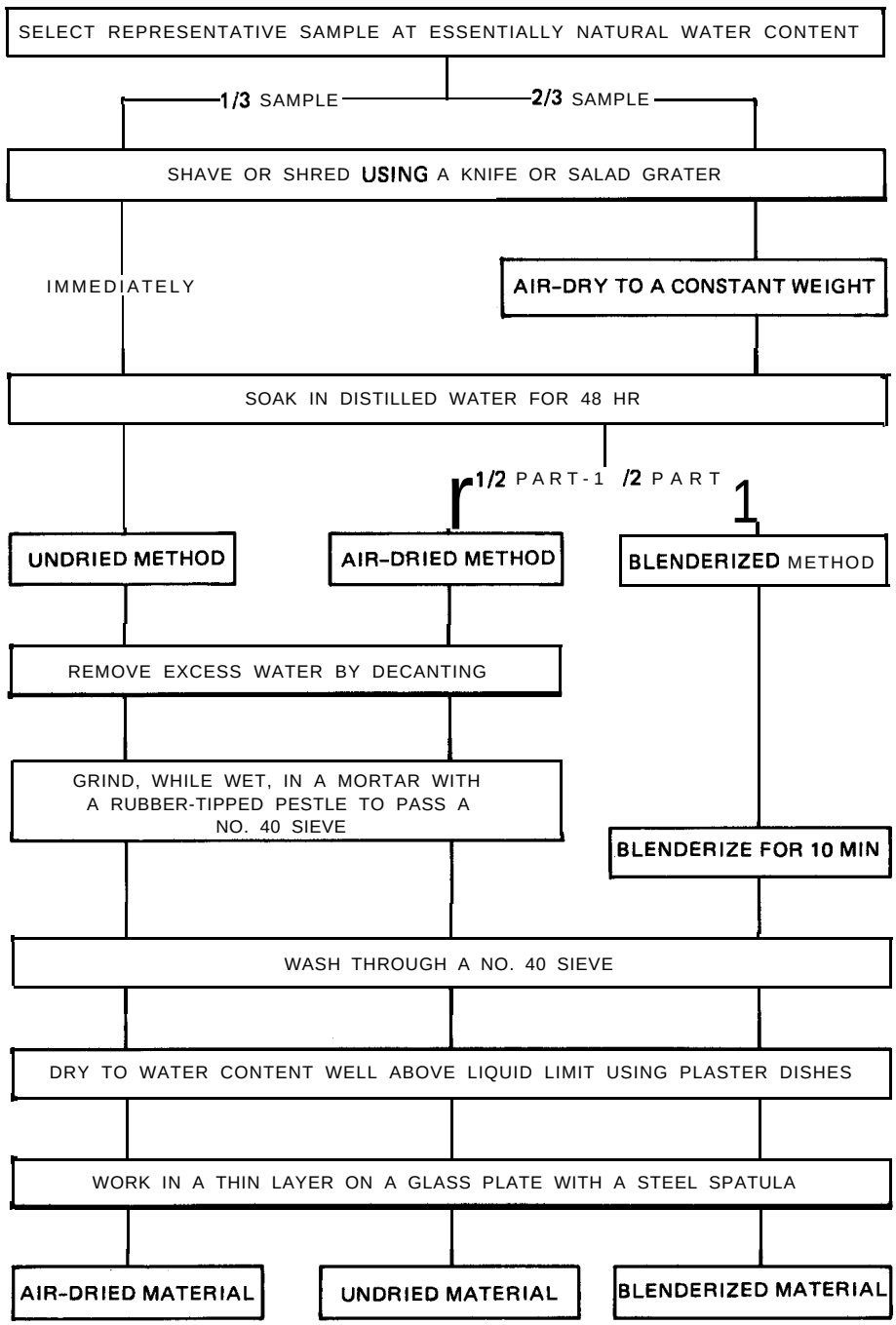


Figure 9. Flow diagram showing the three standard methods of preparing clay shale materials

* decanting, grind the wet material in a mortar with a rubber-tipped pestle and wash through the 425-µm (No. 40) sieve. Remove excess water using a plaster-of-Paris dish lined with filter paper. Work material at a water content above the liquid limit in a thin layer on a glass plate with a steel spatula until no further reduction in the size of lumps can be achieved.

(3) Air-dried. Shave or shred material at essentially natural water content and dry to a constant weight in an atmosphere with a temperature less than 50°C (120°F) and a relative humidity less than 30 percent. After a constant weight is attained (and after a drying period at least 48 hr), soak the material in distilled water for at least 48 hr. After removing excess water by decanting, grind the wet material in a mortar with a rubber-tipped pestle and wash through the 425-µm (No. 40) sieve. Remove excess water using a plaster-of-Paris dish lined with filter paper. Work material at a water content above the liquid limit in a thin layer on a glass plate with a steel spatula until no further reduction in the size of lumps can be achieved.

10. POSSIBLE ERRORS. Following are possible errors that would cause inaccurate determinations of liquid and plastic limits:

a. General.

(1) Specimen not representative. As described in paragraph 4a., the liquid and plastic limits must be determined using the same mixture of soil as that used for determinations of natural water content or for other tests. Care should be taken when using the trimmings from preparation of other test specimens that material is as close as possible. *

* (2) Specimen improperly prepared. The specimens must be thoroughly mixed and be permitted to cure for a sufficient period before testing. Erroneous results may be caused by the loss of colloidal material when removing particles coarser than the No. 40 sieve or by testing air-dried or oven-dried soils.

(3) Inaccurate determination of water contents. The possible errors described in paragraph 6 of Appendix I, WATER CONTENT - GENERAL, would greatly affect the computed liquid and plastic limits because of the small quantities of material available for the water content determinations.

(4) Computational mistakes.

b. Liquid Limit Test

(1) Improperly constructed or adjusted liquid limit device.

(2) Worn parts of liquid limit device, especially at point of contact between the cup and the base or worn tip of grooving tool.

(3) Soil at point of contact between the cup and the base. Removal of the cup for shaping and grooving the soil pat will also ensure that the bottom of the cup and the top of the base are clean. Any soil that has dropped onto the base can be removed with one stroke of the back of the hand just before replacing the cup.

(4) Loss of moisture during test. Erratic and erroneous results may be causing by drying of some soil mixtures unless the test is performed in a humid room. *

* c. Plastic Limit Test

(1) Incorrect final thread diameter. A length of 1/8-in.-diameter metal rod close at hand will help in estimating this diameter accurately.

(2) Stopping the rolling process too soon. If there is any doubt as to whether the thread has crumbled sufficiently, it is better to roll the thread once more than to stop the process too soon.

*

LIQUID AND PLASTIC LIMIT TESTS

For use of this form, see EM 1110-2-1906.

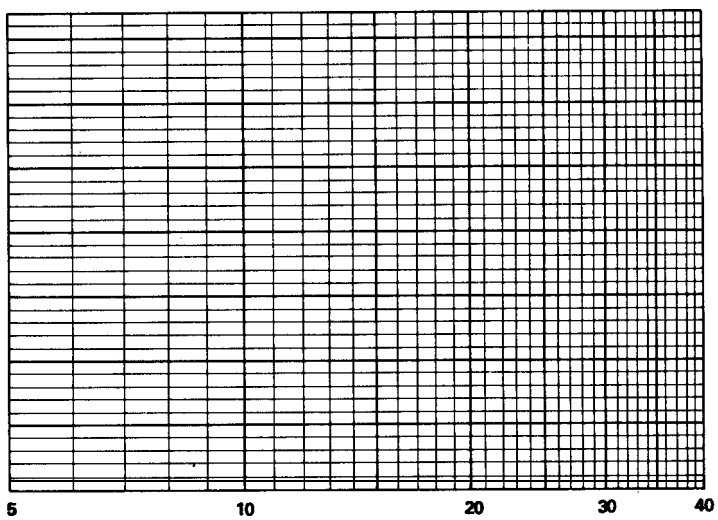
DATE _____

PROJECT _____

BORING NO. _____ SAMPLE NO. _____

LIQUID LIMIT

	RUN NO.	1	2	3	4	5	6
	TARE NO.						
WEIGHT IN GRAMS	TARE PLUS WET SOIL						
	TARE PLUS DRY SOIL						
	WATER W_w						
	TARE						
	DRY SOIL W_s						
	WATER CONTENT, % w						
	NUMBER OF BLOWS						



LL _____

PL _____

PI _____

Symbol from plasticity chart _____

	RUN NO.	PLASTIC LIMIT 1	2	3	4	5	NATURAL WATER CONTENT
	TARE NO.						
WEIGHT IN GRAMS	TARE PLUS WET SOIL						
	TARE PLUS DRY SOIL						
	WATER W_w						
	TARE						
	DRY SOIL W_s						
	WATER CONTENT, % w						
	PLASTIC LIMIT						

REMARKS _____

TECHNICIAN _____ COMPUTED BY _____ CHECKED BY _____

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PLATE III-1

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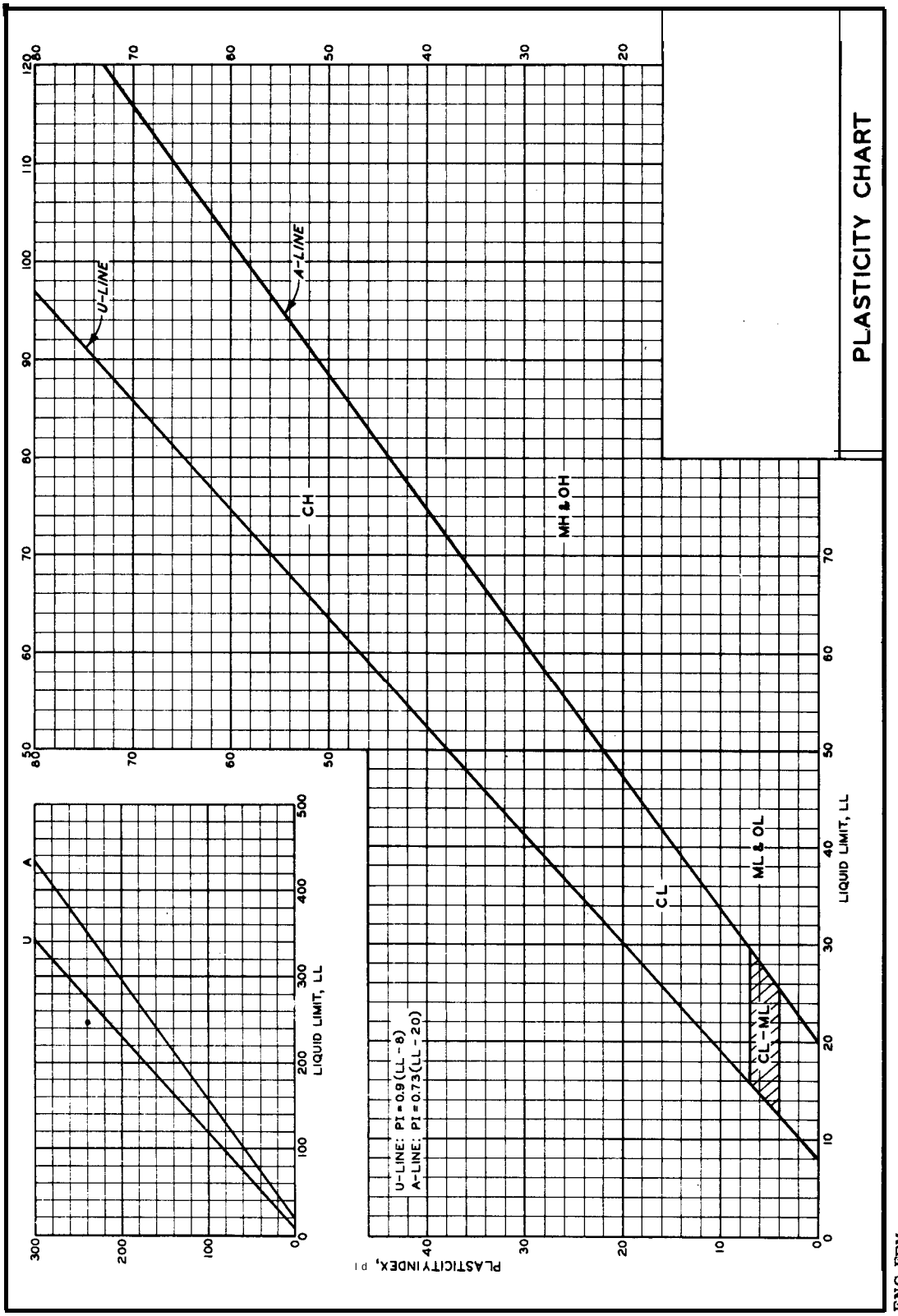
PLASTICITY CHART
U-LINE
A-LINE
CH
MH & OH
CL
ML & OL
CL-ML
U-LINE: PI = 0.9(LL - 8)
A-LINE: PI = 0.73(LL - 20)
LIQUID LIMIT, LL
PLASTICITY INDEX, PI
TRANSLUCENT
4334
(EM 1110-2-1906)
ENG FRM
JUN